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The purpose of this report is to assemble information concerning the early stages in the life history of the shrimp, *Penaeus setiferus* (Linnaeus), which supports the most valuable commercial fishery of the South Atlantic and Gulf of Mexico regions of the United States.

P. setiferus is an organism of high reproductive potential. A count made by the authors on the ripe ovaries of a female, 172 mm. total length with spermatophore attached, revealed a total of approximately 860,000 eggs. Burkenroad (1934) states that the ovary of a large shrimp may contain 500,000 eggs. Heldt (1938) counted about 800,000 eggs in the ovaries of *P. trisulcatus,* a European species of similar size and closely related to *P. setiferus.* It may be expected, therefore, that a female will produce from 500,000 to 1,000,000 eggs in a single spawning.

Description of the Egg

The size of the ripe ovarian egg has been given by Weymouth, Lindner and Anderson (1933) as ranging from 0.25 to 0.33 mm. in diameter with an average of 0.277 mm. Burkenroad (1934) believed the egg to be about two-thirds this size, or about 0.185 mm. Later he changed this estimate to "—about 0.25 mm. or less," (Burkenroad, 1939). Pearson (1935), through the use of a plankton net, secured nauplius-bearing eggs varying in diameter from 0.38 to 0.42 mm. Later he reports (Pearson, 1939) that the diameter of twenty-five live eggs, also secured with a plankton net, uniformly measured 0.28 mm. Gutsell (1936) obtained measurements ranging from 0.192 to 0.300 mm. on ripe eggs from a female with spermatophore attached. He found that fresh oocytes dissected out in sea water were about 0.30 by 0.36 mm. Much of the variation in the data cited may be due to varying age of the eggs and varying manner in which they were handled (some were measured fresh, others after fixation).

According to Pearson (1939) "the egg of *P. setiferus* is demersal and sinks promptly in still sea water." It is "non-adhesive and spherical" and "possesses a thin transparent membrane, or chorion, that in living and preserved eggs shows a characteristic purplish-blue color in reflected light under the microscope."

Larval Development

Our knowledge of the larval development of *P. setiferus* depends largely on the work of Pearson (1939). To quote from the summary of his paper: "The larval development of *Penaeus setiferus,* the common commercial southern shrimp, consists of ten distinct stages excluding the demersal spherical egg. These stages

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are made up of five forms generally included under the name of nauplius, three forms included under the name of protozoea, and two forms included under the name of mysis." In addition to these ten larval forms, Pearson describes two post-larval stages which precede the true adult form.

In brief, the larval development of *P. setiferus* requires from two to three weeks. Some twenty to twenty-four hours after the egg is spawned the nauplius breaks the chorionic membrane and emerges. Its ovoid body, of 0.30 to 0.34 mm. in length, bears a single, simple eye and three pairs of oar-like appendages which are to become eventually the first and second antennae and the mandibles. Although this minute organism is to a great extent at the mercy of the prevailing currents, it is capable of some movement. In the next twenty-four to thirty-six hours the nauplius undergoes five successive molts to become a protozoea of approximately 1 mm. in length. It now has seven pairs of appendages, a pair of sessile compound eyes in addition to the ocellus, and a complete alimentary tract consisting of mouth, esophagus, stomach, intestine, and anus. Prior to this stage the food of the nauplius has been the yolk material carried over from the egg. This food supply is now exhausted and henceforth the protozoea must capture its own food if it is to survive. This transitional period is without doubt a critical one in the animal's life history.

The third protozoea stage is followed by the first mysis, which is about 3.5 mm. in length, possesses fourteen pairs of functional appendages, and on the abdomen five pairs of buds which will soon become the pleopods. In the second mysis the pleopods are well developed, and rudimentary gills have made their appearance on the thoracic somites. With the succeeding molt the organism ends its larval phase and assumes the general proportions of a miniature adult. At the end of two post-larval stages and fifteen to twenty days after hatching, the young shrimp is only 5 to 6 mm. in length and is still planktonic. During this period of early development, the young shrimp have moved from the saline offshore spawning area to the brackish inside marshes, bays, and estuaries (Weymouth, Lindner and Anderson, 1933). Upon reaching these "nursery grounds" they adopt for the first time, it is believed, a benthic existence.

The factors responsible for this inshore movement of larval and post-larval *P. setiferus* have not been determined. We believe, however, that for the young to reach the nursery grounds they must encounter a favorable incoming current. While capable of some movement, and perhaps responsive to a salinity gradient, they would certainly be quite helpless against out-going currents. *P. setiferus* has a long spawning season, which in Louisiana extends from March to September; consequently, at intervals during this period the young are bound to encounter favorable conditions for their inshore migration.

Although spawning usually takes place offshore, schools of adult shrimp have been known to approach the coast and spawn close to inlets. When such a spawning occurs, the eggs may be swept through the passes on incoming currents, and the larvae may reach the nursery grounds within a few hours.

Young Shrimp

As stated above and previously reported by Weymouth, Lindner, and Anderson (1933), young shrimp approximately 7 mm. in length are found during the early

spring months in the brackish inside areas which serve as their nursery grounds for the next four to eight weeks of their existence. This habitat is a rich feeding ground characterized by shallow water, muddy bottoms, rather widely fluctuating seasonal temperatures, and moderate to low salinity. Numerous seine and frame-net collections in these areas have yielded quantities of small shrimp 7 to 10 mm. in length; whereas frequent hauls with the same gear during the same period along the ocean and Gulf beaches have failed to yield any *P. setiferus* of this size, although other species of shrimp were found.

As the young grow, they move from the shallow waters of marsh, bayou, and lagoon into the deeper creeks, rivers, and bays, making their first appearance on the inside fishing grounds when about 50 mm. long. In Louisiana the lower limit of the size distributions obtained from operations with commercial gear in the fishery was 43 mm., in Georgia 58 mm., and in Texas 63 mm.

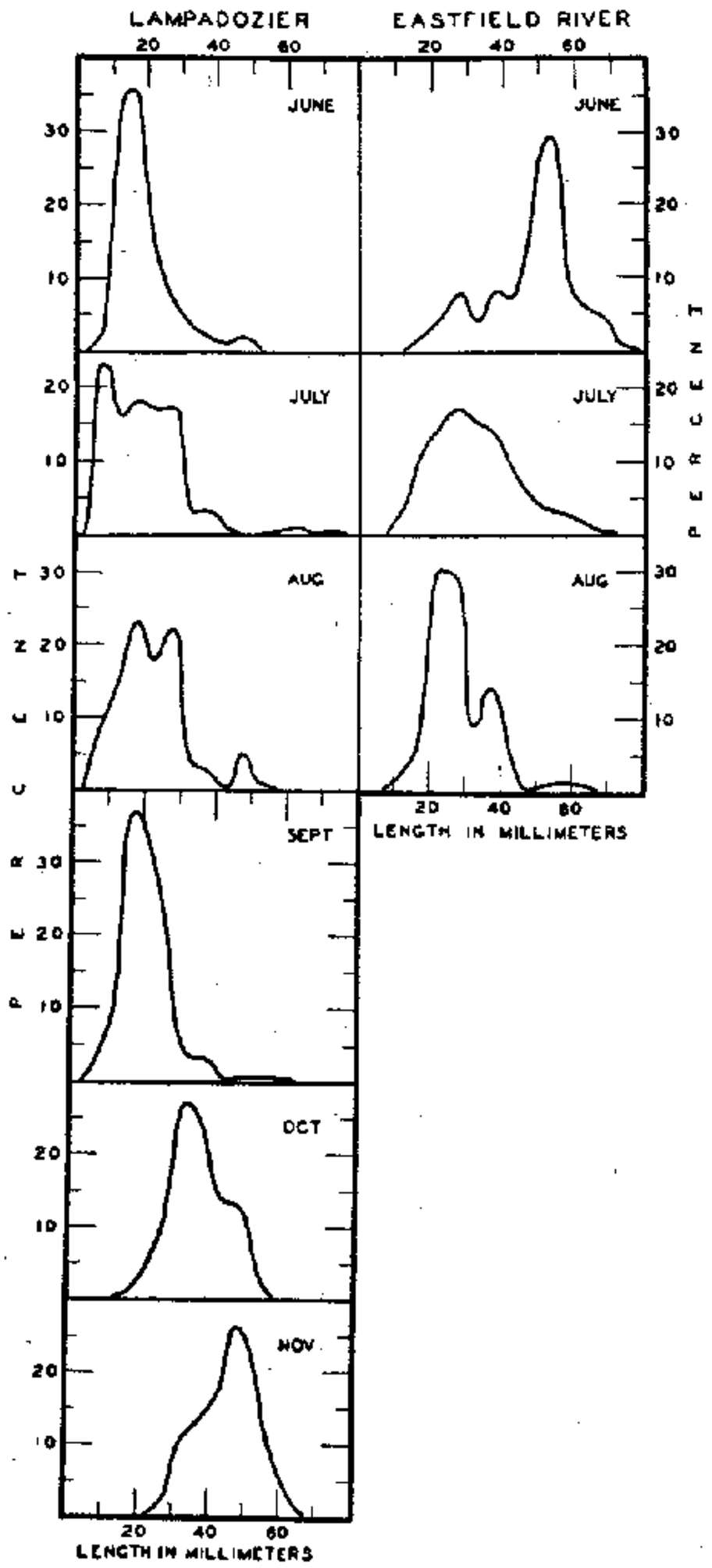

FIGURE 1. Size distribution of young shrimp (*Penaeus setiferus*) seined from the nursery ground areas of Lampadozier and Eastfield River, Georgia. Males and females combined. For the Lampadozier series the curves are based on 200 shrimp in June, 200 in July, 100 in August, 200 in September, 100 in October, and 92 in November. The Eastfield River series are based on 100 shrimp in June, 400 in July, and 100 in August.

To illustrate the population on a typical nursery ground area, the length frequency distributions of small shrimp from seining and frame-net operations in two localities in Georgia are shown in Figure 1. The Lampadozier series, which covers a period from June to November, was obtained entirely by seining in one particular locality in a section representing the inner reaches of the nursery grounds. The young shrimp of the Eastfield River series were somewhat larger in size; they represent collections (covering a period from June to August) taken with both seines and frame-nets in an area midway between the upper nursery grounds (represented by the Lampadozier series) and the lower bays or sounds. The apparent reverse order in the sizes of shrimp in the Eastfield River series is due, it is believed, to the exodus late in June of the larger shrimp, a product of an early spawning, and the entrance in great abundance into the River in July and August of the young from the peak spawning period of May and June.

In the Lampadozier section during June and July the average length of the shrimp was 18 mm. with a range from 8 to 48 mm., although in July a few scattered longer individuals were obtained. In August the average length had increased to 23 mm. with a range from 8 to 53 mm. During September the average length was maintained at 23 mm. with the bulk of the population ranging between 8 and 38 mm., although scattered individuals up to 78 mm. in length were secured. By October the average length had increased to 38 mm. with a range from 18 to 53 mm. During November the average length rose to 48 mm. with a range of 28 to 63 mm.

From the Lampadozier data, the increase in the lower limits of the length frequency distribution from 8 mm. in September to 18 mm. in October and to 28 mm. by November, indicates that after September no new recruits were appearing on the nursery grounds. September marks the end of the spawning season in Georgia (Anderson, Lindner and King, 1948).

Relationship of Nursery Grounds to Commercial Catch

The distribution of the shrimp fishery in itself obviously indicates that passes and the adjacent inland waters are of prime importance to the species. Louisiana, which has a combination of more passes and a vastly larger inland water area landward of these passes than any other state, produces about two-thirds of the shrimp caught each year throughout the entire South Atlantic and Gulf region. Likewise, Georgia and South Carolina, whose shorelines have the most numerous passes and favorable inside waters on the South Atlantic Coast, develop the greatest numbers of shrimp in that section. As a consequence, we conclude that the number of openings to the outside waters and the extent of favorable nursery grounds are two of the major physical factors influencing the production of shrimp in the various sections of the fishery.

In addition to the number of passes and the area of nursery grounds, a coastal or nearby offshore area of relatively shallow water, high salinity, and mud or clay bottom also seems to be a requisite. The Florida peninsula between Fort Pierce on the east coast around almost to St. Marks on the west coast lacks this and likewise lacks shrimp. It is not yet known whether this factor is a requirement of adults or larvae or of both.

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